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EVALUATING INJURY PREVENTION PROGRAMS: THE OKLAHOMA CITY SMOKE ALARM PROJECT

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ABSTRACT

Evaluation of injury prevention programs is critical for measuring program effects on reducing injury-related morbidity and mortality or on increasing the adoption of safety practices. During the planning and implementation of injury prevention programs, evaluation data also can be used to test program strategies and to measure the program's penetration among the target population. The availability of this early data enables program managers to refine a program, increasing the likelihood of successful outcomes. The Oklahoma City Smoke Alarm Project illustrates how an evaluation was designed to inform program decisions by providing methodologically sound data on program processes and outcomes. This community intervention trial was instituted to reduce residential fire–related injuries and deaths in a geographic area of Oklahoma City that was disproportionately affected by this problem. The distribution of free smoke alarms in targeted neighborhoods was accompanied by written educational pamphlets and home-based follow-up to test whether the alarms were functioning correctly. Early evaluation during the planning and implementation phases of the program allowed for midcourse corrections that increased the program's impact on desired outcomes. During the six years following the project, the residential fire–related injury rate decreased 81% in the target population but only 7% in the rest of Oklahoma City. This dramatic decline in fire-related injuries in the target area is largely attributed to the free smoke alarm distribution as well as to educational efforts promoting awareness about residential fires and their prevention.

Evaluation is the process of determining whether programs are appropriate, adequate, effective, and efficient and may indicate if a program has unexpected benefits or creates unexpected problems (Deniston & Rosenstock 1970). Evaluation is an ongoing process: It begins with an idea for a particular program, is interwoven with activities throughout the life of the program, and is completed in the final assessment of whether program objectives were met and program effects sustained over time (Thompson & McClintock 1998). Determining that a program is not effective or has negative consequences is as important as knowing that a program substantially improved outcomes. This ensures that resources are not wasted and persons are not harmed. All injury prevention programs should be evaluated, but not necessarily in the same way or at the same level of methodological rigor (National Committee for Injury Prevention and Control [NCIPC] 1989). Interventions that have been subjected to thorough evaluation in a variety of settings and found to be effective do not require the same intensity of evaluation as new and untried interventions.

The purpose of this article is to discuss the importance of evaluating injury prevention programs and to illustrate how the evaluation process and results inform program decisions, using a community-based residential fire injury prevention program as an example. The Oklahoma City Smoke Alarm Project was implemented in 1990 in an effort to decrease injuries associated with residential fires in an area of Oklahoma City that had a high rate of these injuries. The primary component of the intervention was a targeted smoke alarm distribution program. This was accompanied by written education material and periodic follow-up to test whether the smoke alarms distributed were functioning correctly (Mallonee, Istre, Rosenberg, et al 1996). Evaluation was an integral part of the program from its inception, and early evaluation results led to changes in the intervention design. These changes allowed the program to achieve results beyond its original goals and objectives.

THE IMPORTANCE OF PROGRAM EVALUATION

In the past, many interventions were undertaken based on intuition, advocacy, or legal considerations rather than on scientific evidence of what works and what does not work to reduce unintentional injuries (Institute of Medicine 1998a). Because many of these prevention programs are well received

Figure 1 - Stages of Program Evaluation

Formative Evaluation	The process of testing program plans, messages, materials, strategies, and activities for feasibility, appropriateness, acceptability, and applicability to the program and the target population. Formative evaluation is generally used when a new program is being developed or an existing program is being modified.
Process Evaluation	The mechanism for testing whether a program is reaching the target population as planned, such as by counting the number of people or households reached. Process evaluation should begin when a program is implemented and continue throughout the life of the program. Programs often are fine tuned during the implementation phase because of process evaluation results.
Impact Evaluation	It measures the changes in the target population's knowledge, attitudes, beliefs, or behaviors associated with the program. These changes are measured prior to beginning the program and during and/or following the program.
Outcome Evaluation	Used to determine how well the program achieved the goal of reducing morbidity and mortality. Baseline data must be collected for an adequate time period prior to and following the implementation of the program to determine program effects. Documenting changes in morbidity and mortality also requires a large study population and analysis of the same data for a similar population that did not receive the program (control group).

Sources: Thompson & McClintock 1998; Fitz-Gibbon & Morris 1987.

and popular, funding often continues in the absence of scientifically rigorous evaluations. Currently, however, there is a movement toward implementing interventions of demonstrated effectiveness. Nonetheless, relatively few communitybased injury prevention programs have been rigorously evaluated to the extent that would justify the resources allocated to these programs (Klassen et al 2000).

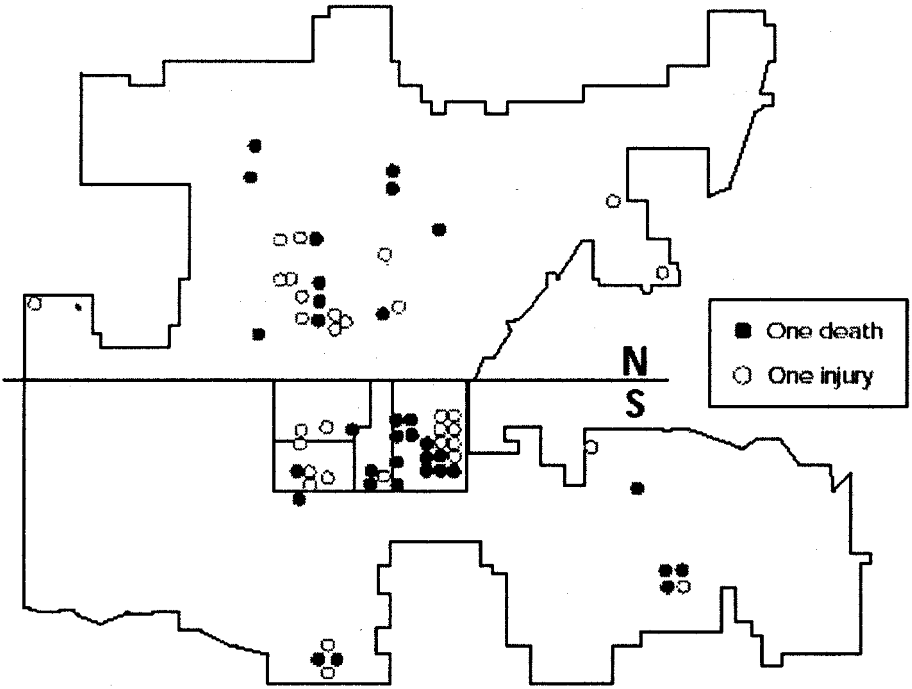
Many potential reasons exist for the lack of rigorous evaluations. Program staff and funders often place a higher priority on service delivery (that is, distributing bicycle helmets, car seats, etc.) than on evaluating program effectiveness. Program managers may not understand the importance of evaluation, may lack staff trained in evaluation, or may be concerned that negative findings will doom a program. Additionally, target populations often are too small or the injury events being studied are too rare to demonstrate significant effects on injuries or deaths, and program managers often are not aware of other appropriate evaluation measures. Even when programs are small and have few resources, evaluation is essential, and program managers should design their efforts so that useful evaluation data are collected throughout the program. Without evaluation, it is not possible to determine whether a program benefits or harms the target population (Thompson & McClintock 1998), or wastes valuable resources.

While the most common use for evaluation is to determine whether proposed program goals and objectives are met, evaluation data is often used in other ways. Many evaluations compare the cost and effectiveness of multiple approaches to a problem, often leading to a program's redesign. Demonstrating a program's effectiveness to the target population, the public, policymakers, researchers, and practitioners also advances knowledge and can enhance funding and future program development in injury control. Because of the multiple ways evaluation data are used, most programs need to design evaluation plans that incorporate four stages of evaluation (see Figure 1). Each of these stages was addressed in the Oklahoma City Smoke Alarm Project.

THE RATIONALE FOR THE OKLAHOMA CITY SMOKE ALARM PROJECT

More than 800 children and adolescents under age 20 died of unintentional firerelated injuries in the United States during 1996 (Grossman 2000). Residential fires account for 90% of all childhood burn deaths, and in many states, more children die in residential fires than as motor vehicle occupants or pedestrians (Wilson, Baker, Teret, et al 1991). The majority of fire-related deaths are due to the poisoning effects of smoke inhalation and asphyxiation, not the burn itself (Baker, O'Neill, Ginsburg & Li 1992; Gormsen, Jeppesen & Lund 1984). Smoke alarms are an

Figure 2 - Injuries Due to Residential Fires in Oklahoma City, September 1987 to April 1990



Source: Mallonee et al 1996.

effective, inexpensive means of providing early warning of fire (NCIPC 1989; Karter 1994; National Fire Data Center [NFDC] 1980; Derry 1979) and are 50% to 80% effective at preventing death or injury (NFDC 1980; Hall 1994). While more than 90% of U.S. homes have a smoke alarm, as many as 25% to 34% of these alarms may be nonfunctioning (Hall 1994; Smith 1994; Centers for Disease Control 1986). The absence of functional smoke alarms in residential dwellings is a risk factor for residential fire–related injury or death (NFDC 1980; Birky, Halpin Caplan et al 1979; Runyan, Bangdiwala, Linzer et al 1992). An estimated 80% of fire-related deaths occur in homes without working smoke alarms (U.S. Fire Administration 1990).

In Oklahoma, burns and smoke inhalation are the leading cause of death among children ages one to four (Oklahoma State Department of Health 1999). In an effort to better assess the occurrence of injuries, the Oklahoma State Department of Health (OSDH) made hospitalized and fatal burns/smoke inhalation a reportable condition in 1987. The OSDH acquired data from hospitals, the chief medical examiner, and the local fire department as part of a statewide, population-based injury surveillance system. Analysis of the surveillance data indicated that a total of 312 residential fire–related injuries occurred statewide between September 1987, when surveillance began, and April 1990, just before this program was implemented. Among persons injured in residential fires, children under five years of age had the highest annual mortality rate (6.8 per 100,000 population) of any age group. Among children injured in residential fires, 64% (41 out of 64) died.

Oklahoma City had the highest residential fire injury rate in the state. Sixty-six people in Oklahoma City were injured in residential fires between September 1987 and April 1990; 34 of these people died (52%). Six children under five years of age suffered nonfatal injuries, and five children died (45%). When Oklahoma City injury data were linked to fire department run data and then mapped according to place of occurrence, a high-risk geographic population was identified. This 24-square-mile "target area" included 16% of the Oklahoma City population, but it experienced 45% of the total residential fire injuries and deaths (see Figure 2). The target area included a population of 73,301 persons and 34,945 residential dwellings (single- or multiple-family dwellings, excluding apartments). The residential fire injury rate in the target area was more than four times higher than the rest of Oklahoma City (15.3 and 3.6 per 100,000 population, respectively) (Mallonee et al 1996). In the target area, only 4 of the 30 fatal and nonfatal injuries (13%) occurred in homes with functioning smoke alarms.

The demographic characteristics of the target population showed a higher proportion of Hispanic, American Indian, and other nonblack minorities, lower household income and property/rental values, and fewer high school graduates compared with the rest of Oklahoma City. Prior to the intervention, the statewide prevalence of smoke alarms was estimated to be 70%, although the prevalence in Oklahoma City households was not known. However, data from the Oklahoma City Fire Department indicated that homes in the target area in which fires had occurred were less likely to have a smoke alarm (23%) than were homes in the rest of Oklahoma City that had a fire (40%).

To address this important public health problem, a community-based intervention that included a smoke detector giveaway program in conjunction with a fire and injury prevention educational effort was implemented in the target area of Oklahoma City in May 1990. Prior to the Oklahoma City intervention, no comprehensive evaluation had been conducted to determine whether a program to increase the prevalence of smoke alarms in a high-risk population would reduce fire-related morbidity and mortality.

THE EVALUATION OF THE OKLAHOMA CITY SMOKE ALARM PROJECT

The evaluation of the Oklahoma City Smoke Alarm Project used the four types of evaluation discussed previously (Thompson & McClintock 1998). The *outcome evaluation* focused on the program's primary goal—to decrease hospitalized and fatal burn and smoke inhalation injuries associated with residential fires by 50% in the targeted population. This component of the evaluation relied on the injury surveillance system developed by the OSDH. Two programmatic issues critical to the primary injury outcomes also were evaluated. Specifically, the effectiveness of methods of distributing alarms and soliciting household participation in the program was measured in the *process evaluation*. The subsequent and appropriate use and function of the smoke alarms distributed was measured in the *impact evaluation*. Finally, as a result of the demographic composition of the target population, educational material provided to participants in conjunction with the smoke alarm distribution was refined during the *formative evaluation* and written at a third-grade reading level in both English and Spanish.

The state health agency had the lead role in this project and was responsible for identifying the target population, acquiring funding, and implementing and evaluating the intervention. The local health and fire departments, the Red Cross, and a large coalition of volunteers from the community also were actively involved. Evaluation began when the intervention was designed, was ongoing throughout the intervention, and has continued for nine years (though only six years are reported here) to ascertain whether the program's effects have been sustained over time. The rest of Oklahoma City (outside the target area) was used as a comparison population because of the similarities in characteristics (such as weather, fire department response, city ordinances) that could affect or confound the evaluation of this program.

Components of the Program

The two major components of this communitybased project were (1) the distribution and testing of smoke alarms in residential dwellings and (2) written educational material provided to each individual participant and selected populations (schools, churches, media, and so on). This material addressed prevention of the major causes of residential fires resulting in injury in the target area, including children playing with fire (47%), smoking (17%), and flammable liquids (13%) (Douglas, Mallonee & Istre 1998). The material also covered 911 emergency calls, escaping fires, and installing and maintaining smoke alarms.

Based on the estimated baseline prevalence of smoke alarms statewide (70%), this intervention was designed to distribute smoke alarms to more than 10,000 homes in the target area and compare two methods

Table 1 - Inspection Results at 3, 12, & 48 Months: Alarm Installation & Functional Status in Oklahoma City, 1990 to 1994

Alarm Status	3 Months	12 Months	48 Months
Alarm installed & functioning	65%	53%	46%
Alarm not yet installed	20%	6%	4%
Alarm/battery did not function	2%	5%	7%
Removed the batteries	2%	10%	19%
No longer had the alarm	7%	14%	9%
Moved & took the alarm with them	4%	11%	15%
Sample size	875	5,617	749

Source: Mallonee et al 1996

of distributing them. The first method distributed smoke alarms by "canvassing" the area using a fire truck slowly driving down each street, intermittently sounding its siren, and broadcasting a public announcement that volunteers were distributing free smoke alarms curbside to households without an alarm. The second distribution method required participants to go to a neighborhood fire station to obtain a smoke alarm.

While the canvassing method solicited participation of household occupants at the time of distribution, the areas that required visiting a fire station to obtain an alarm used three different methods of distributing flyers to solicit household participation in the program. These flyers educated residents about the risks of residential fire injuries, notified them of the residential fire prevention program, and listed the location of fire stations, dates, and times where smoke alarms were distributed for free. In one area, the flyer was mailed to all residents; in another area, the flyer was distributed only in public places; and in the final area, volunteers placed the flyer in residential doors. The flyers mentioned that alarms also were available by calling the Red Cross and would be installed by program representatives upon request.

PROCESS EVALUATION: MEASURING SMOKE ALARM DISTRIBUTION

To evaluate which distribution method most effectively reached the target population, the baseline prevalence of smoke alarms in the target area was estimated prior to the program via a targeted telephone survey (Douglas et al 1998). The baseline prevalence was then reevaluated very early in the program by surveying a random sample of homes. The household survey was conducted by off-duty uniformed firefighters who visited the selected addresses unannounced and requested information on the presence or absence of a functioning smoke alarm in the home, verified the presence and function of alarms in the home, and installed or replaced alarms or batteries when necessary. Based on this survey, the estimated baseline prevalence of smoke alarms in the target area was 66% (Douglas, Mallonee, & Istre 1999). Thus, an estimated 11,881 of the 34,945 target area homes were in need of an alarm.

In May 1990, 3,564 smoke alarms were distributed to 3,433 homes in the target area of Oklahoma City. In addition, approximately 350 batteries were distributed to homes with alarms that needed a battery. Evaluation of the impact of the two distribution methods revealed that 31% of all homes in the canvassed area received a smoke alarm compared with only 6% in the other areas combined. More homes in need of a smoke alarm also were reached in the canvassed area (68%) than in the other three areas combined (17%). Finally, 56% of all alarms were distributed in the canvassed district, although it accounted for only 17% of homes in the target area (Douglas et al 1998).

In addition to reaching more homes in need than the other methods, canvassing also allowed volunteers to distribute more alarms per hour (5.9) than the other two methods (3.1) (Douglas et al 1998). Since only one-third of the 10,000 smoke alarms were distributed during May 1990, and only 17% of the population in need in the noncanvassed area had been reached, program managers decided to canvass the rest of the target area. By November 1990, the entire area had been canvassed and a total of 10,100 smoke alarms had been distributed to 9,291 homes; nearly 80% of the *homes in need* and approximately 25% of *total homes* in the target area received an alarm during

Table 2 - Final Results: 72-Month Follow-up, Annual Injury Rate per 100,000 Population and Injury Rate per 100 Residential Fires, Oklahoma City, 1990 to 1996

	Injury Rates per 100,000 Population			Injury Rates per 100 Residential Fires		
Location	**9/87-4/90**	**5/90-4/96**	**Rate Change**	**9/87-4/90**	**5/90-4/96**	**Rate Change**
Target area	15.35	2.96	-81%	5.02	1.20	-76%
Rest of city	3.63	3.37	-7%	2.95	2.19	+12%

Source: *Innovative Strategies to Prevent Residential Fire-Related Injuries* 1998. State and Territorial Injury Prevention Director's Association 1998.

the program. During the second year of the program, batteries were distributed to all participants. During the third year, postcards reminding residents to change the detector battery were mailed to all participating households. No contact was made with participants during subsequent years.

Impact Evaluation: Use and Functional Status of Smoke Alarms

Determining whether alarms distributed by the program were installed and maintained was an important question for evaluating program effectiveness, because smoke detectors must be installed and functioning appropriately to reduce fire-related injuries, and only 6% of the smoke alarms distributed were installed by program representatives. To answer this question, off-duty uniformed firefighters visited a random sample of homes that had received an alarm and assessed the alarm status at three intervals over four years following the intervention (see Table 1) (Mallonee et al 1996). Nearly two-thirds of the alarms were installed and functioning within three months of implementing the program. At 48 months, nearly 50% were still installed and functioning. The primary reasons for the decrease in the number of functional alarms at 48 months were batteries being removed from the alarms and participants moving and taking the alarms with them (see Table 1).

Outcome Evaluation: Impact on Morbidity and Mortality

The primary goals of this evaluation were to estimate the impact of the smoke detector giveaway program on residential fire–related injuries and deaths in the target area, and to determine whether any impact observed was sustained over time. These questions were answered by calculating fatal and nonfatal residential fire injury rates per 100,000 population and per 100 residential fires in both the target area and in the remainder of Oklahoma City and by comparing these rates over time. Fire-related injury rates were calculated between the time when surveillance began until the smoke detector giveaway program was implemented (September 1987 to April 1990), and again for six years following program implementation (May 1990 to April 1996). The injury rate associated with residential fires decreased 81% in the target population, but it decreased only 7% in the remainder of Oklahoma City during this six year time period. Similarly, the injury rate per 100 fires decreased 76% in the target area, but it increased 12% in the rest of Oklahoma City (see Table 2). Among children under five years of age, only two were injured in the target area during the six years after intervention. It is estimated that at least 60 injuries and deaths were prevented in this high-risk area of Oklahoma City during the six years following the implementation of the smoke alarm giveaway program.

The 81% decline in the rate of injuries in the target area following the intervention is striking and cannot be explained on the basis of the smoke alarm giveaway program alone. It is likely that educational efforts, increased awareness about preventing the most common causes of residential fires, and publicity about the program also contributed to the decline in injuries (Mallonee et al 1996). In addition, the relatively small number of injuries during the study period could have made the observed decline more variable.

Some of the decrease in fire-related injury rates may have resulted from "regression to the mean." (James 1973). This phenomenon occurs when the observed effect of an intervention is higher than expected because the baseline incidence has fluctuated by chance above its long-term average. In this instance, by picking an area of the city that had the highest rate of fire-related injuries, one would expect the rate to be reduced in subsequent years, even without an intervention. However, it is unlikely that this phenomenon had a major effect on these results, for several reasons. Data on the injury incidence for nearly three years was analyzed before the intervention, and the sudden, marked decline in the injury rate coincided precisely with the program's implementation and persisted for at least six years. The number of injuries per *100 residential fires*, as well as *per population*, also was analyzed, minimizing any potential bias introduced by a substantial change in the number of fires. While the number of fires per 100 homes was high in the target area prior to the intervention, it continued to be higher there even after the intervention. In addition, the type of housing in and demographic characteristics of the target area were known to be associated with a high risk of residential fire–related injuries, and it seems unlikely that these factors would have changed rapidly (Mallonee et al 1996).

While randomized controlled trials (RCTs) are considered the gold standard in evaluating the effectiveness of interventions, they are expensive, time-consuming, and not always feasible (DiGuiseppi & Roberts 2000; Institute of Medicine 1998b). Community intervention trials such as the Oklahoma Project can generate valuable evaluation results, but do have limitations, including the unavailability of data to control for "confounding variables"—characteristics that differ between the target and comparison communities and independently influence the outcome (Rothman 1986). However, it is unlikely that potential confounders, such as changes in the population prevalence of smoking or drinking or changes in weather conditions, were present only in the target area and thus caused or substantially contributed to these results (Mallonee et al 1996).

CONCLUSIONS

This article discusses the importance of evaluating injury prevention efforts. Evaluation encompasses assessments of a program's feasibility, efficacy, effectiveness, and cost effectiveness. Perhaps the most important use of evaluation data is to assist managers, policymakers, funders, practitioners, and researchers to expand successful interventions to larger groups of at-risk populations. Evaluation data also help managers create the best possible programs, learn from mistakes, modify programs to capitalize on the most effective strategies, and monitor progress toward program goals and objectives. Whether large or small in scope, evaluations of injury prevention programs should be designed to provide a sound assessment that can be replicated (Rossi & Freeman 1985).

The Oklahoma City Smoke Alarm Project illustrates how evaluation was used to guide programmatic decisions and alter interventions in a real-world setting. Using surveillance data, it was demonstrated that an intensive, targeted smoke alarm distribution program significantly reduced residential fire–related injuries and deaths in a low-income population. Process evaluation during the first month of the program also showed that distributing smoke alarms door-to-door was significantly more effective at reaching this population than promotional methods requiring residents to go to a fire station to receive an alarm. In response to this finding, the program was refined and the entire target area was canvassed to strengthen the program's impact.

The impact evaluation of the functional status of the alarms suggests that most alarms were installed even though they were just handed to the participants. While having program staff install the smoke alarms may have increased the prevalence of alarms in participating households, it is not clear whether this would have significantly decreased the number of alarms that had the battery removed or that were not functioning at the time of follow-up. Future programs should evaluate whether installing every alarm substantially increases the number of homes with functioning alarms during the several years following a giveaway program.

The evaluation of the functional status of the alarms suggests that smoke alarm programs using alkaline battery–powered alarms, like the ones used in the Oklahoma City intervention, should address the need for annual battery replacement. The impact of using smoke alarms powered with lithium batteries also should be explored. These batteries —which are estimated to last 10 years and usually have a silencer button to disable the alarm if there is nuisance smoke such as from cooking—may increase the prevalence of functioning smoke alarms at follow-up and decrease the likelihood of occupants removing batteries. The disadvantage of alarms that use lithium batteries is that they cost two to four times that of standard alkaline battery–powered smoke alarms, and their effectiveness and cost effectiveness in community injury prevention programs have not been evaluated. Finally, evaluations should be conducted on the effectiveness of residential sprinkler systems in conjunction with smoke alarms.

Funding for the entire nine-year period reported here (1987 to 1996) came from a variety of state and federal funding sources. It is estimated that more than 50% of the three-year research project costs were expended for the program evaluation. Current federal awards to design, implement, and evaluate prevention programs are for two- to three-year projects and may not provide adequate funding to complete a thorough and meaningful evaluation within a realistic time frame. As this example indicates, rigorous evaluation requires a longer followup period than the traditional award of two to three years (Lescohier, Gallagher & Guyer 1990). Practitioners and researchers must work with policymakers at the local, state, and federal levels to ensure that more resources are allocated to enhance evaluation capabilities and to increase the duration of grants and cooperative agreements awarded to implement and evaluate new community-based programs.

In summary, the Oklahoma City Smoke Alarm Project demonstrates that combining a well-conceived program design and a rigorous evaluation can lead to a successful community-based intervention that reduces the burden of injury by preventing death, disfigurement, and disability. Although this model was used to reduce residential fire injuries, the basic framework is applicable to a broad array of childhood injuries.

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